NEW WORLD VISTAS: AIR & SPACE POWER FOR THE 21ST CENTURY

Recommendations from the New World Vistas Study are divided into the following topics and subtopics:

AIRCRAFT and AIR VEHICLES Environmental Protection Theater Air Operations Missile Defense IR Technology Stealth and Low Observable Technology UAVs New Weapons Aircraft Defense	**MUNITIONS** Pyrotechnics (near term) Explosives (near term) Airborne Ballistic Interceptor Aircraft Self-Protection Missile ECM Cruise Missile Miniature Autonomous Munitions Hard Target Penetrators Enabling Technologies
DIRECTED ENERGY Global Precision Optical Weapon/Virtual Presence UAV-Theater Missile Defense	**MOBILITY** **SENSORS**
HUMAN SYSTEMS AND BIO-TECHNOLOGY	**SOFTWARE TECHNOLOGY** COTS for BM/C3
INFORMATION TECHNOLOGY **INFORMATION APPLICATIONS** **MATERIALS** **STRUCTURAL MATERIALS** (near term recommendations) Aircraft Engine Materials Aging Systems Pollution Prevention Optics and Electronic Materials Sensor Applications Transitioning Advanced Materials into Flight Systems	**SPACE TECHNOLOGY** Vehicles for Space Lift (near term) Vehicles for Space Lift (far term) Satellite Bus Technologies (near term) Communications
STRUCTURAL MATERIALS (far term recommendations) Aircraft Engine Materials Materials Developments **PROPULSION** Rocket Propellants (near term) Fuels and Lubricants (near term) Rocket Propellants (far term) Scramjet Engine Development **ELECTRICAL POWER** Energy Generation and Storage (near term)	**SPACE APPLICATIONS** Information Warfare Commercialization Distributed Satellite Systems Communications Global Positioning, Time Transfer, and Mapping Observation and Battlefield Awareness Space Control Orbital Debris Reduction Force Projection Modeling, Simulation, and Analysis

AIRCRAFT and AIR VEHICLES

Continue strong investment in air vehicle technologies:

1) Long-range aircraft
2) Uninhabited aircraft
3) Special operations aircraft
4) Long-endurance aircraft
5) Modular vehicles
6) Hypersonic vehicles
7) Future attack aircraft

Vigorously pursue and fund enabling technologies for revolutionary air vehicle concepts. Closely couple cost and system capability

- Establish a research effort to define the fundamental principles of cost determination
- All S&T projects should consider the proper balance between life cycle cost (LCC) and capability
- The Air Force should pursue an active experimental aircraft and flight research program
- The Air Force should take timely action to define and implement a program for modernization of old facilities and construction of new test facilities that ensures the adequacy of national test facilities to support future military air vehicles
- The Air Force should stop internal aircraft cockpit design work, and instead depend on aircraft manufacturers
- The Air Force should stop internal ejection seat research and development, and instead depend on aircraft manufacturers

Environmental Protection

The Air Force should stop internal environmental protection research in Air Force labs

Theater Air Operations

Air Force must define its vision and state its required new capabilities: Needs to produce concept of operations for theater air operations in the 2020-2030 era that will focus and prioritize advanced technology and advanced system development

Missile Defense:

Air Force needs major new capabilities to dominate future theater air operations: must be able to defeat both ballistic and cruise surface-to-surface missiles and a wide variety of surface-to-air missiles
The Air Force should stop buying bandwidth to the theater (cross listed with INFORMATION APPLICATIONS)

IR Technology:

Aggressively develop and exploit infrared technology, both offensively and defensively:

1) infrared signatures of vehicles
2) infrared sensors for a range of applications including infrared missiles
3) infrared countermeasures (particularly against missiles having focal plane array seekers)

Stealth & Low Observable (LO) Technology:

- Continue our dominance in fielding Low Observable technology-stealth.
- Continue to field more stealthy systems for which no potential adversary can afford a counter-stealth-based defensive system

UAVs
Field UAVs to gain major new warfighting capabilities

New Weapons:
Field eight classes of new revolutionary systems:
1) An "invisible air vehicle,"
2) Speed-of-light weapons
3) An electro-magnetic weapon for disabling enemy RF sensors
4) Small, precise, tailored-effects air-to-ground weapons
5) A bistatic radar system for battlefield use
6) Light-weight, affordable, launch-on-demand surveillance satellites
7) Next-generation systems to replace C3I systems and platforms
8) A global-range transatmospheric aerospace vehicle for strike and reconnaissance

Aircraft Defense
For aircraft defense follow the development path from present technology through systems capable of disabling or destroying vital missile components, ultimately to conformal phased arrays of high power diodes integrated into the structure of the aircraft (FotoFighter), providing capabilities ranging from surveillance and tracking to thermal kill of attacking missiles. Specific studies are required to define the most promising path toward cost reduction of diode arrays and development of high precision threat detection and tracking systems

DIRECTED ENERGY

Global Precision Optical Weapon/Virtual Presence
Conceptual studies need to define the development plans for the technologies needed to realize the following vision: Space-based or space-relayed DE weapons will move beyond their initial role in boost-phase defense to a multitude of combat missions. With the potential to destroy or disable anything that flies in space or in the air, or striking any target on the surface of the land or sea, these weapons will revolutionize the character of warfare. Two technologies need radical innovation:
1) multi-meter sized optics with diffraction limited performance, and
2) techniques for pointing and tracking to 50 nanoradian accuracy

UAV-Theater Missile Defense
- Concept studies must refine designs and identify a program for the required technology development for a UAV-based weapon for theater missile defense. It must be more compact and less expensive than the ABL, and it will have a shorter lethal range and a smaller magazine
- Develop and demonstrate compact, high power diode pumped solid state lasers (ten to one thousand times higher in power than those at the several kilowatt power level)

The Air Force, in collaboration with the other Services and DARPA, should support a program with the goals of reducing the acquisition costs of laser diode pump arrays to:
1) Less than $2/peak watt and $25/average watt by 2000
2) Less than $0.2/peak watt and $2/average watt by 2005

- Emphasize development of phased arrays of laser diodes. DoD activities must remain cognizant of ongoing developments in other areas which can dramatically improve ability to meet longer term goals and not be focused exclusively on more engineering-oriented short-term approaches with limited potential

- Develop and exploit adaptive optics and phase conjugation for weapon beam delivery to target
- Initiate joint efforts between the USAF and NASA directed toward development of large, lightweight, space-deployable optics. Activities should be closely accompanied by development and testing of adaptive optical correction systems using; for example, nonlinear phase conjugation which will be required to provide diffraction-limited optical beam delivery to compensate for figure errors in the large, lightweight optics
- Undertake an experimental evaluation of the lethality of small diameter, high irradiance, short wavelength radiation against antiaircraft missiles
- Develop a variety of improved high power microwave (HPM) sources to provide parameters required for use on weapon delivery platforms ranging from aircraft, UAVs, and missiles to people. Demonstrate HPM weapon potential in realistic scenarios and address fratricide issues. Identify and harden systems susceptible to RF
- The Air Force must invest in revolutionary technologies for high power generation (greater than 100 kiloWatts), such as nuclear power, laser power beaming, and electrodynamic tethers (cross-listed with **PROPULSION**)
- The Air Force should invest in commercial technologies for high-efficiency energy conversions and storage, as necessary to adapt to its needs

HUMAN SYSTEMS AND BIO-TECHNOLOGY

- Air Force leadership must declare as the first principle that all Air Force systems are, and will be designed in the future as, human-centered systems. System maintainers and developers cannot cut human-in-the-loop considerations first and engineering considerations last
- Air Force must commit to a consistent level of investment in cognitive science research and a requirement of cognitive scientists that they produce some incremental products from their research
- Air Force personnel management must recognize the inevitability of advances in testing and profiling human capabilities that will make it possible to find exceptionally capable individuals and match them to the most mission-critical positions. The Air Force must begin the process of adjusting long-standing personnel policies to accommodate these advances.
- The Air Force must buy advanced training as it becomes available and maintain its cadre of in-house training technologists who can tell acquisition leadership what to buy and what to avoid
- The Air Force must establish as acquisition policy that simulators and other training equipment will provide the level of fidelity required for cost-effective training and no more. The Air Force must establish valid criteria to measure training effectiveness and provide a basis against which the cost effectiveness of investments in simulators and other training equipment is gauged.
- Air Force leadership must require the Air Force S&T program to define the level at which human control will be exercised and the specification of the human-system interface that will exercise this control
- DoD and the Air Force must declare that the principle of totally integrated comprehensive systems for each corporate entity and whole industries will be implemented with every choice being made so as to place the human operator/user at the center

The Secretary of the Air Force must assign responsibility to a senior biologist of the Air Force for ensuring that advances in biology will engender new strategies for:

1) Creating new materials
2) Designing new structures, and
3) Manufacturing new end-products

- SECAF through the senior biologist charged with this responsibility should ensure that advances in biology are being integrated at the right time and in appropriate ways into AF

S&T and personnel management programs, exercised through both command and Surgeon General channels
- The Secretary of the Air Force must assign to a senior biomedical research physician in the Air Force, the responsibility for ensuring that advances in biology and medicine that will produce new strategies for enhancing human performance and limiting performance decrement are being integrated at the right time and in appropriate ways into the Air Force S&T and personnel management programs, exercised through both command and Surgeon General channels
- Air Force leadership must invest in the psychological, biological and computer sciences sufficiently to force the frontiers of these sciences forward in areas where the Air Force benefits

Air Force leadership must also invest systematically and long term in the development of enabling technologies based on the psychological, biological and computer sciences including
1) Human modeling (cognitive and physiological)
2) Workload and fatigue management systems
3) Personnel assessment instruments
4) Precision-guided training
5) Distributed interactive simulation for training, and
6) Information management responsive to human cognitive processes.

INFORMATION TECHNOLOGY (IT)

The Air Force must make long term R&D investments in technologies for:
(1) Wideband, secure, world-wide information networks
(2) Information transfer over the backbone-to-mobile platform link (the last "N miles")
(3) Evolutionary technologies for data fusion, including automatic target recognition
(4) Commercial technologies for information storage, retrieval, and processing technologies and protocols. The Air Force should invest as necessary to adapt these to its needs
(5) Multi-level data fusion and information distribution. Information fusion comprises both signals and symbolic knowledge
(6) A widely available knowledge web of tens to hundreds of millions of pieces of knowledge. The AF shares in the research costs and develops AF-specific knowledge for AF needs
(7) Software architectures that work with AF-specific knowledge, reusable components, safety-critical components, real-time systems, and other military-oriented capabilities
(8) The automatic indexing of images by their semantic meaning in terms of military objectives (intelligent image retrieval)
(9) Automatic capture of the rationale for plans during planning activities
(10) Reasoned –action and learned-action agents whose goals are AF-specific
(11) COTS software components and CASE tools enhanced to meet AF combat needs (such as security, survivability, real-time performance, and scalability)
(12) Architecture for "just-in-time" information systems and networks "when you need it."

Commercial technologies the Air Force should invest in as necessary to adapt to its needs: Neural networks and artificial intelligence
(13) COTS for BM/C3 (cross listed with **SOFTWARE TECHNOLOGY**)
Carefully exploit commercial information technology to improve warfighting capability: must define system architecture which exploits this technology operationally, based on the doctrine of dynamic planning and execution control, including force management, mission control, and engagement control
(14) Multi-agent planning software
(15) Software that is survivable and that displays graceful degradation
(16) Realistic modeling and simulation for training. Use COTS software where available

(17) System design through acquisition; planning and decision making. This will include component interoperation; believable semi-autonomous forces; transition from virtual to actual system acquisition (in a non-proprietary way); validation verification, and accreditation
(18) Augmented reality—the overlaying of synthetic, spatially synchronized cues and structures on real-time, real-world activity for training and for the maintenance of complex systems
(19) Human-computer interaction capable of sensory-matched control of all UAVs
(20) The technologies and rules of engagement for information warfare
(21) Telepresence, the real-time translation of the human senses and physical dexterity into otherwise inaccessible spaces with possibly “non-human” scaling factors

Defocus AF investments from the following areas that will be well-handled by the commercial sector

1) High capacity communications “backbones”; global telephone networks; world-wide wireless infrastructure, Internet, automated teller machines (ATM)
2) Cryptography routinely embedded in systems
3) Compression (except intelligent compression)
4) Multimedia technologies
5) Natural language understanding, including speech understanding
6) Computer displays
7) Data mediators, request facilitators, and information broker software
8) Basic directed-action software agents
9) Software for the “business” functions of the Air Force, i.e., logistics, personnel, finance, etc.

Next information technology (IT) steps that should be taken:

1) Air Force laboratories must rethink their IT R&D programs in the light of the 1995 New World Vistas report
2) The Air Force should rethink its advanced weapons system design from the info-centric point of view
3) The Air Force should rethink the education, career path, and reward structure for its officers and airmen in light of the IT future projections in the New World Vistas report
4) The Air Force should rethink its acquisition strategy in the light of rapidly evolving advanced IT capability in the commercial sector

INFORMATION APPLICATIONS

- Get the right knowledge to the right place at the right time for all aerospace missions. Research should be directed toward automating the tasks of data fusion
- Achieve information dominance to enable the execution of AF missions through the unconstrained but protected use of the Battlespace Infosphere, including segments that the AF does not control
- Protect all Air Force computers, software, and data regardless of platform or location, particularly those involved in warfighting. Follow best commercial practice and military security policy. Research into the issues of computer security in this rapidly evolving technology.
- Achieve global communication between the air, ground, and space assets of the Air Force, as well as those with whom we operate. Conduct research associated with the evolution of the Air Force toward a densely internetted environment
- The Air Force should invest in commercial technologies for high-data-rate RF communications as necessary to adapt to its needs
- Maximize the speed and quality of Air Force coordination, planning, and execution. Fund research supporting new capabilities for command and control

- Dominate the Information Battlespace, with steps towards an Air Force view of information warfare
- Develop doctrine needed for the use of information in dynamic command and control of joint forces (Air Force participating in future Joint operations)
- Increase speed in key fusion applications through operator cueing. Set automated data fusion as a battlespace information fusion research goal.
- The Air Force should stop buying bandwidth to the theater (cross listed with **THEATER AIR OPERATIONS**)
- Research strong security for Air Force netted computer systems
- Increase the number of airborne platforms with data communication links, better interoperability, and global dissemination broadcasts (short term)
- Research cheap two-way global communication among all Air Force platforms
- Construct a system prototype that includes automated planning and scheduling tools, and hierarchical modeling and simulation (short term)
- Research a distributed collaboration system that marries real-time automated planning with globally connected human interfaces
- Establish a central authority to define and control the information architecture, and its sensor segment, as a system of systems (cross-listed with **SENSORS**)
- Develop an Air Force view of information warfare, and develop the software tools needed to monitor an evolving DoD-wide Battlespace Infosphere (short term)
- Research possible futures for software munitions (cross-listed with MUNITIONS)
- Invest near term to integrate doctrine with technology for joint warfighting
- The Air Force should rethink deployment of the MILSTAR C2 System (cross listed with **SPACE APPLICATIONS**, <u>Observation and Battlefield Awareness</u>)

MATERIALS

- Explore novel component/materials design philosophy that provides for refurbishment of fatigue damaged areas of structural components with new materials to restore original functionality
- The Air Force needs to develop new mechanisms to ensure that U.S. industrial base for advanced materials capabilities and infrastructure does not erode beyond the point of being responsive to Air Force materials needs.
- Commit to maintaining robust R&D programs and capabilities in innovation and development of materials for long-range critical Air Force needs, and not rely solely on commercial sources.
- The National Policy with regards to advanced materials should ensure technological advantage
- Commit to ensuring new funding and programs which integrate advanced materials into current and future systems, in order to help counter the downturn in military aerospace R&D
- Commit to demonstrating and incorporating new materials, which offer significant payoffs in flight systems and rocket technology
- Commit to ensuring continued performance of aging aircraft and missiles. In order to reduce costs, the Air Force should move from programmed depot maintenance to condition-based maintenance. This change will require support for development of new technologies in nondestructive evaluation/inspection (NDE/I), situational sensors, and life prediction techniques
- Commit to increasing resources for materials and processes R&D to alleviate the increasing cost of operating and maintaining the aging fleet
- Commit to aggressively pursuing new technologies for affordability that lessen the impact of advanced materials and Air Force operations on the environment. Environmental issues must be supported at the highest levels in the Air Force command structure

- Commit to adopting life-cycle costing (LCC), which recognizes that early investments in materials and processes can dramatically lower life cycle costs of both new and upgraded systems
- The Air Force must invest in revolutionary technologies for rugged thermal protection systems for reusable spacelift or hypersonic vehicles
- The Air Force must consider potential cost of disposal of materials and systems and make the appropriate investments that can minimize those costs

STRUCTURAL MATERIALS (near term recommendations)

1) Continue to focus on implementation of enhanced fiber-reinforced composites with emphasis on combined multifunctional structural and electromagnetic characteristics
2) Explore opportunities for unexplored structure applications like hypersonic weapon systems
3) Continue evolution of revolutionary new process methods that guarantee reliability and durability while reducing component costs
4) The Air Force should initiate the equivalent of an in-house X-plane program to enhance technology transition of new materials (composition or processing) to aircraft
5) Fund key technologies for low-cost composites for airframes

Aircraft Engine Materials (near term)

1) Successfully develop advanced materials for the Integrated High Performance Turbine Engine Technology (IHPTET) initiative to enable turbine engines with improvements such as a 100-percent increase in the thrust-to-weight ratio and up to a 50 percent decrease in fuel consumption
2) Key materials and processes for IHPTET are in the following classes: intermetallics, metal matrix composites, and ceramic matrix composites
3) Fund key technologies for high-temperature materials in advanced turbofan engines
4) Develop other classes of unique new engine materials for emerging non-manrated hypersonic systems

Aging Systems (near term)

1) Develop new methods for reducing the cost of maintaining the aging fleet
2) Explore the following approaches: a) inspection without coating removal, b) direct fabrication of replacement components, c) remote inspection of aging systems
3) Develop life prediction methodologies
4) Validate corrosion prediction, and
5) Refurbish materials and processes

Pollution Prevention (near term)

Invest in alternative green processes to replace existing hazardous material processes

Optical and Electronic Materials (near term)

1) Apply commercial technology in silicon electronics
2) Invest in the areas of a) IR sensors, b) radar, c) lasers, and d) high-temperature, adverse-environment electronics

Space Applications (near term)

Develop advanced high performance composites, both carbon-carbon and organics for thermally managed, lightweight, multifunctional structures and components

Transitioning Advanced Materials into Flight Systems (near term)

1) Create a program for rapid introduction of advanced materials into flight test systems
2) Establish an advanced materials applied research & test program (using existing vehicles as test beds) at the Air Force Flight Test Center

STRUCTURAL MATERIALS (far term recommendations)

The Air Force must invest in revolutionary technologies for lightweight integrated structures combining reusable cryogenic storage, thermal protection, and self-diagnostics to enable a responsive reusable launch capability

Aircraft Engine Materials (far term)

1) Aim research at applying innovative concepts, including processing and compositional and microstructural modifications
2) Develop and synthesize new materials, making use of innovative schemes for materials processing
3) Develop new systems applications, where improved or alternative materials will be used, possibly in conjunction with changes in design, which will lead to marked improvements in performance
4) Develop better aircraft engine materials, and a) Devise solutions to problems limiting the application of existing attractive materials; b) Synthesize new materials making use of innovative schemes for materials processing, such as laminating nano-scale composites; c) Evolve new systems applications, possibly in conjunction with changes in design, that lead to marked improvements in performance including thrust/weight, resulting in savings in operational costs
5) The Air Force must invest in revolutionary technologies for high-temperature materials for engines

Materials Developments (far term)

1) Develop prediction-based computational methods that can be used to design and synthesize high temperature materials that will be tailored for specific applications/components
2) Develop nanophased organic materials and nanostructured composite materials which integrate sensing, energy conversion, and structural functions
3) Develop new mechanisms for the systematic creation of new material structures and properties
4) Develop micro-electromechanical systems (MEMS) to exploit revolutionary multifunctionality for systems at small scale approaching molecular dimensions
5) Develop dynamic stealth materials that allow the pilot/system to change the signature characteristics of multifunctional materials at will to meet real-time requirements
6) Develop self-monitoring and self-healing materials to permit in-flight battle damage repair
7) Develop sprayable structural composite materials to cover surfaces with coatings that have one or several of the following functions: switchable antennas, tunable transmittance, energy storage capacity
8) Explore organic and composite nanoparticles for recyclable airframe materials
9) Explore materials to enable enhanced optoelectronic and all-optical information gathering, transmission, processing, and storage. Processability, switching speed, and tunability give molecular and polymeric materials the greatest potential
10) Explore computer development of new materials and processes with experimental validation and test
11) Explore functionally designed and fabricated material structures using localized placement of material (eventually down to the molecular level), similar to methods employed in the semiconductor chip industry
12) Explore path-dependent prediction of structure lifetime using real time sensor input of environmental parameters (temperature, stress, corrosion) coupled with deterministic damage models

PROPULSION

Rocket Propellants (near term)

1) Implement major improvements in solid fuel motors (and similar improvements in liquid fuel motors) by incorporating advances in binders and oxidizers (5-20 percent improvement in mass-to-orbit or a 5-15 percent increase in specific impulse)
2) Develop advanced hybrid systems with improved performance (goal of 350 sec for a strap-on) by using new oxidizers, TPE binders, gel binders, and new fuels like aluminum hydride
3) Pursue and fund enabling technologies for high specific-energy controllable propellant, i.e., 15% increase
4) Use cryogenic high energy density materials and materials like metallic hydrogen (specific impulse greater than 1500 sec) to revolutionize access to space (performance several times greater than LOX/H2)

Fuels and Lubricants (near term)

1) Continue developing endothermic fuels to enable higher-performing turbines
2) Make advances in lubricants and seals that are critical to meet mission requirements of aircraft and space vehicles of the future

Rocket Propellants (far term)

1) The Air Force must invest in revolutionary technologies for high-energy-density chemical propellants to enable spacelift with high payload mass fractions. Specific impulses of 1000 seconds or greater (in high-thrust systems) should be the goal of this effort
2) The Air Force should explore hybrid propellant systems having ultrahigh energy densities to replace liquid propellant systems
3) The Air Force must invest in revolutionary technologies for high performance maneuvering, including electric propulsion and tethers for momentum exchange. The goal for electric propulsion is near 100% efficiency, thrusts greater than tens of Newtons, and specific impulses of thousands of seconds.
4) The Air Force must invest in revolutionary technologies for high power generation (greater than 100 kiloWatts), such as nuclear power, laser power beaming, and electrodynamic tethers (cross-listed with **DIRECTED ENERGY**)

Scramjet Engine Development

Pursue and fund enabling technologies; creating a specific plan with milestones for scramjet engine development

ELECTRICAL POWER

Energy Generation and Storage (near term)

1) Develop advanced secondary batteries and supercapacitors having energy densities and power densities in excess of 500 W×hr/kg and 10 kW/kg respectively, for use in advanced spacecraft
2) Develop advanced fuel cells such as lithium oxide, ground-based power sources that directly use (i.e. without reforming) liquid fuels or that employ biofuels

MUNITIONS

- Research possible futures for software munitions (cross-listed with **INFORMATION APPLICATIONS**)
- Exploit advanced technology to field far more effective conventional weapons

Pyrotechnics (near term)

1) Develop advanced flares for aircraft protection to defeat state-of-the-art missile seeker heads

2) Develop metastable interstitial composites to create extremely high temperatures for destroying chemical biological warfare agents

Explosives (near term)

1) Exploit an opportunity for the Air Force to bring to the field advanced explosives and directed energy charges based on recently invented energetic materials
2) Develop technologies to allow tuning of explosive charges (to fill the gap between conventional and nuclear weapons)
3) Implement advanced thermites
4) Exploit nanoformulated explosives to improve yield and control

Airborne Ballistic Interceptor: Conduct a detailed concept definition study focused on the ABI concept that could effectively intercept theater ballistic missiles during their boost/ascent phase, and move ahead into system development

Aircraft Self Protection Missile

1) Conduct a concept definition study that evaluates and selects between the reaction controlled projectile and a small, agile missile
2) Conduct a technology demonstration for the "reaction controlled projectile."

ECM Cruise Missile: Sponsor a multi-year technology demonstration of an ECM warhead that could be carried on a cruise missile and possess effective electronic countermeasure technology to shut down the enemy's electronic systems for sensing, data processing, communication, and command and control

Miniature Autonomous Munitions: Put together a miniature autonomous weapons program that will provide some near-term options and develop the technology base for the future.

1) Emphasize kills per sortie on all munitions to increase the pace of warfare
2) Conduct a technology demonstration of the LOCAAS Munitions showing autonomous battlefield target detection, acquisition, and destruction of mobile targets
3) Pursue sensor and signal processing technology to improve target acquisition and classification; establish specific milestones and address the expanded target spectrum
4) Demonstrate the capability to autonomously attack fixed targets
5) Set up a five-year program culminating in a technology demonstration of powered flight for extended range of these miniature autonomous systems

Hard Target Penetrators: Conduct research (with specific milestones) to demonstrate a small (approximately 20 kg high explosive warhead) high velocity penetrator. The delivery concept could be built around the hypervelocity missile developed for the ABI (airborne ballistic interceptor)

Enabling Technologies: The Air Force should pursue and fund enabling technologies. The Air Force should create specific plans with milestones for the following evolving technologies:

1) High energy explosives, i.e., a 60% increase in delivered energy
2) Electronic Countermeasure warhead technologies
3) Airborne lasers for self defense

MOBILITY

Systems that embody the most revolutionary technologies for potential mobility improvements that should be explored include:

1) Information dominance system
2) Global range transport
3) Precision/large scale airdrop
4) Directed energy self-defense system, and
5) Virtual reality applications

SENSORS

- Establish a central authority to define and control the information architecture, and its sensor segment, as a system of systems (cross-listed with **INFORMATION APPLICATIONS**)
- Develop and field a new family of multispectral sensors: must be made modular and standardized and must make maximum use of commercially developed technologies
- Improve multifunction radio frequency apertures
- Improve multifunction electro-optical/infrared modules
- Develop a family of air-monitored, unattended ground sensors
- Develop a family of military-capable micro-sensors for use in airborne, spaceborne, and ground sensor systems to assess acoustic, seismic, inertial, pressure, biochemical, and other phenomena
- Develop tags for air-monitoring the movement of materials and equipment
- Stress sensor affordability through emphasis on revolutionary and evolutionary signal processing concepts
- Exploit the advantages of the multidimensionality offered by multiple sensor regimes
- Develop Automatic Target Recognition (ATR) and Automatic Sensor Cueing (ASC) for sensor systems

Initiate programs to develop the following new concepts:
1) Target Reporter --Long endurance unmanned air vehicle with range of air and ground sensor/tag reporting for persistent battlefield surveillance
2) Integrated Arrays of Distributed Unattended Ground Sensors
3) Underground Target Surveillance
4) All-Condition Concealed Target Detection
5) Weather Surveillance and Prediction
6) Modular, Integrated, Multifunction Phased Array Based Electro-Optical System
7) Low-Cost Space-Based Surveillance. These programs should include:·a) a family of military-capable microsensors for acoustic, seismic, inertial, pressure, bio/chemical, and other phenomena;·b) a variety of doping materials and tagging devices to help locate and track weapons systems, munitions, vehicles, and personnel; and ·c) a program in unattended ground sensors, using dopants, tags and internetted sensors from above, together with communications and fusion processing, to obtain detailed battlefield surveillance

Fund Key Enabling Technologies for:
1) Airborne wind-measurement sensors
2) Synthetic sensory environment for virtual reality applications

The Air Force should invest in evolutionary sensor technologies:
1) Large, sensitive focal plane arrays and associated readout and cooler technologies for hyper- and ultraspectral sensing of small low-contrast targets and long-wavelength detection against the cold background of space
2) Active sensors
3) Microelectromechanical systems (MEMS), including on-chip optics
4) Commercial technologies for image processing, coding, compression, and very large scale integration (VLSI) architectures. The Air Force should invest in these as necessary to adapt to its needs

SOFTWARE TECHNOLOGY

The Air Force should procure COTS (commercial off-the-shelf) software to meet its needs, when it is available and able to satisfy military needs (for example, office automation products). The use of COTS should be extended to tools for enabling Information Technology (IT).

COTS for BM/C3 (cross listed with **INFORMATION TECHNOLOGY**)
Carefully exploit commercial information technology to improve warfighting capability: must define system architecture which exploits this technology operationally, based on the doctrine of dynamic planning and execution control, including force management, mission control, and engagement control

The Air Force should stop:
1) Software development of software tools
2) Development of compilers
3) Mandatory use of Ada language for computers and software

SPACE TECHNOLOGY

- The Air Force should take the lead in establishing collaborative planning, advocating appropriate changes to U.S. Space Policy, and encouraging coordinated execution of space technology development among NASA, DoD, NRO, DoE, and industry auspices
- The government (including the military services, NASA, and other federal agencies) should continue to invest and continue efforts in space technology to take the least expensive route that will meet future needs in space

Vehicles for Space Lift (near term)
The Air Force should invest in evolutionary technologies for launch vehicles:
1) Engines, upper stages, and solar thermal propulsion; and
2) Vehicle structures
3) Small launch vehicles commercial technologies adapted to Air Force needs

The Air Force and DoD should stop military only launch access to space, and instead exploit commercial systems

Vehicles for Space Lift (far term)
Field a family of new generation, environmentally friendly launch vehicles that are capable of inserting, on short notice, payloads ranging from 1000 to 100,000 pounds into LEO to meet increased demand for space access. Their propulsion system should consist of entirely recyclable materials and components

Satellite Bus Technologies (near term)
The Air Force should invest in evolutionary:
1) Structure technologies
2) Commercial technologies for spacecraft manufacturing, adapted as necessary to Air Force needs
3) Commercial technologies for vehicle and spacecraft operations, adapted as necessary to Air Force needs
4) Innovative energy storage technologies
5) Attitude control technologies, including attitude sensors and attitude control system (ACS) algorithms
6) Radiation hardening technologies for spacecraft electronics
7) Low-observable technologies
8) Microelectromechanical systems (MEMS) technologies.

Communications
The Air Force should invest in evolutionary technologies for:
1) Very high-rate, long-distance optical communications; and
2) Multi-beam adaptive nulling antennas for anti-jam communications

The Air Force should rethink the design of and investment in dedicated Military Satellite Communication Systems

SPACE APPLICATIONS

Information Warfare:

1) The Air Force should support integrated but dispersed processing and fusing of intelligence and battlefield awareness data to provide our forces the advantage of faster and more expert use of available information
2) The Air Force should advocate the creation of a joint warfare information function to be in charge of all information that influences the outcome of the battle
3) The Air Force should take the lead to define the space system requirements to support offensive and defensive information warfare

Commercialization:

1) The Air Force should develop specific road maps for the exploitation of commercial communications, positioning, environmental and reconnaissance systems that assure availability of these assets from day to day peacetime operations through major regional conflicts
2) The DoD must develop, document and implement an approach to positively incentivize commercial providers of space-based goods and services to do business with the government and to add military-unique functionality to their commercial systems to give the DoD incremental advantage at lowest costs. The key is to establish relationships with commercial providers early in their development cycle.
3) The Air Force representing DoD should establish an integrated product team to
   a) maintain a continuous assessment capability of commercial space systems and their supporting communications and ground infrastructures which may be potentially useful or threatening to the U.S.
   b) act, or enable a clear path to higher authority to recommend action, as a result of these assessments;·and
   c) infuse commercial technology/operational capability awareness throughout the relevant planning, acquisition and operational elements of the USAF
4) The Air Force, representing the DoD, should establish much more effective mechanisms to promote regular dialog, alliances, and investment to interact/participate with US commercial space enterprises in the areas of ·a) standards definition,·b) bandwidth/frequency allocation;·c) joint specifications definition, d) joint development, especially for low-demand but cutting-edge technologies important to the US government; and e) operational control/access/privileges during times of declared national emergency.

Distributed Satellite Systems:

1) The Air Force should create a road map which recognizes the twin realities of inexpensive, single-sensor, small satellites and distributed processing and communications enables a significant advance in reconnaissance, surveillance and battle awareness
2) The Air Force should begin development of a suite of small satellites to complement the evolving national sensors for timely battle field reconnaissance
3) The Air Force should focus, where appropriate, on hybridized, distributed architectures, employing on-board processing, storage and cross-linking now being incorporated in commercial distributed space system designs
4) The Air Force must invest in revolutionary technologies for clusters of cooperating satellites (e.g. high-precision stationkeeping, autonomous satellite operations, and signal processing for sparse apertures)

Communications:

1) The Air Force should develop and implement a global terrestrial and satellite communications architecture whose infrastructure would be built upon both DoD and commercial capabilities
2) Published standards should be established for future communications architectures to be distributed, flexible, scaleable, fault-tolerant, reconfigurable, and transparent to the users
3) The Air Force should advocate the practice that DoD users who can reside on fiber optic arteries should be required to do so, and the warfighters given priority for satellite communications for mobile and tactical users
4) Truly unique military survivable and enduring satellite communications requirements should be identified and implemented through a combination of unique military space systems complemented with appropriate non-military systems and technologies

Global Position, Time Transfer, and Mapping:

1) The use by the DoD of selective availability (S/A) to reduce the accuracy of the C/A code position location should be discontinued. The DoD should stop selective availability of the global positioning system (GPS).
2) Methods and systems should be developed to assure U.S. and allied forces positioning information over limited battle areas while denying similar quality support to the enemy force without seriously affecting essential out of area civil and commercial operations
3) In the long term, the Air Force should aggressively support advanced technology using space systems leading to consistent positioning and mapping accuracy on the order of 30 centimeters. Such space systems should support relative position accuracy in the centimeter range
4) Time transfer to accuracies of a nanosecond or less should be an integral part of any global positioning system to provide synchronization in future communications and information systems. The highly accurate temporal and spatial information should be assigned eventually to all information and serve as the basis for the storage and retrieval of this information

Observation and Battlefield Awareness:

1) In order to exploit fully the available technology to the warfighter's advantage, the Air Force should be a full participant in planning, developing, acquiring, launching, and operating of U.S. military and intelligence space reconnaissance assets
2) Aggressive investment should be continued on methods and technologies to extract information from data at all points of the process. The focus should be on rapid, smart systems to reduce the dependency on humans wherever appropriate. 3) A user-needs driven attitude should prevail within the information acquisition community and a seamless interface should be established with the intelligence community to ensure sharing of data bases, and commonality of objectives. System, and architecture definition and implementation with full warfighter input, recognizing the need for balance among all users, technology and attendant costs should be pursued

The Air Force should rethink the MILSTAR C2 satellite system (cross-listed with **INFORMATION APPLICATIONS**)

Space Control:

1) The Air Force must ensure that its most valuable space assets are safe against attack by third world nations, rogue groups and major powers
2) The Air Force must develop and field a capability to deny, degrade, disrupt, exploit, and if necessary, destroy the use of space assets by others, globally or in a local region
3) The Air Force should continue to study the potential threat posed by space debris and the necessary techniques for its surveillance, mitigation, and removal, if necessary

Orbital Debris Reduction
The Air Force should invest in commercial technologies for orbital debris reduction as necessary to adapt to its needs

Force Projection:

1) The Air Force should broaden the use of space to include direct force projection against surface, airborne, and space targets
2) The Air Force should define and develop microwave and laser space-based weapons for tactical and strategic applications
3) The Air Force should develop space munitions capable of precision strikes against surface and airborne targets
4) The Air Force should invest in space-based weapons technologies for
   a) smart interceptors, and
   b) electromagnetic pulse (EMP) and jamming

Modeling, Simulation, and Analysis (MS&A):

1) The Air Force should quickly press ahead with a joint implementation of a DoD "virtual test bed" for space technical concepts and warfighting CONOPS
2) The DoD must eliminate the boundaries between MS&A for modernization support and MS&A for operations support. A seamless process which includes the joint warfighter in acquisition MS&A and the acquirer in operations support MS&A will be essential for rapid and cost effective reconfiguration of systems of space systems
3) The Air Force, in conjunction with the Army, Navy, Marines, and others, should exploit virtual reality implementations to make space support more readily understandable to the political decision maker and the warfighter by allowing individuals to immerse themselves in the space-terrestrial operations continuum